WATER POLLUTION SOURCES AND PURIFICATION: CHALLENGES AND SCOPE

Editors:
R. M. Belekar
Renu Nayar
Pratibha Agrawal
S. J. Dhoble

Bentham Books

Water Pollution Sources and Purification: Challenges and Scope

Edited by

R. M. Belekar
Department of Physics
Institute of Science
Ravindranath Tagore Road
Nagpur, M.S.
India-440 001

Renu Nayar
Department of Chemistry
D. P. Vipra College
Bilaspur C.G.,
India-495001

Pratibha Agrawal
Department of Applied Chemistry
Laxminarayan Institute of Technology
R.T.M. Nagpur University
Nagpur, India–440010

&

S. J. Dhoble
Department of Physics
R.T.M. Nagpur University
Nagpur
India-440033

Water Pollution Sources and Purification: Challenges and Scope

Editors: R. M. Belekar, Renu Nayar, Pratibha Agrawal & S. J. Dhoble

ISBN (Online): 978-981-5050-68-4

ISBN (Print): 978-981-5050-69-1

ISBN (Paperback): 978-981-5050-70-7

First published in 2022.

Bentham Science Publishers Pte. Ltd.
80 Robinson Road #02-00
Singapore 068898
Singapore
Email: subscriptions@benthamscience.net

CONTENTS

FOREWORD

The authors of this edited book are renowned researchers in the field of water research, photocatalytic degradation, and solar cells. With their research experience, they have edited this book by referring to and analyzing a wide range of literature. This edited book not only covers a critical review of some water research problems but also contains some original research work regarding catalytic degradation. In short, this book reveals the causes of water pollution and its impact on animal life. Moreover, it also discusses various water purification methods developed so far. This edited book further focuses on fluoride contamination in drinking water, its effect on human life, and fluoride removal by using activated alumina modified with different materials. The authors of this book have included original research like that on the degradation of substituted benzoic acid by nanoparticles and analysis of seasonal and spatial variations of water quality of Dulhara and Vedponds in Ratnapur, Chhattisgarh, India. Few chapters of this book cover wastewater treatment using modern methods, the impact of water mismanagement on the environment, and suggestions on the preventive measures for proper water utilization. The authors have made all possible efforts to enhance the usefulness of the book for the research community.

K. G. Rewatkar
Professor in Physics
Ambedkar College
Nagpur-440010, India

PREFACE

Water pollution and its impact on human health are frequently discussed in this age. Several research studies and projects are undertaken and accomplished year after year. However, sustainable water resource management is still a serious concern in most developing countries. Moreover, the problem of water contamination and its purification are greater challenges and a lot of the research tends to be futile. There is, therefore, a need to design and develop appropriate methodologies in order to improve the quality of water. By keeping this view in mind, the present book is written with clear objectives: to develop a basic idea about various challenges in water pollution and their removal.

Regarding the organization, the book consists of seven chapters, well-arranged in a coherent manner.

- Chapter one deals with the different water purification techniques used for safe drinking water production, potential threats, and challenges.
- Chapter two focuses exclusively on fluoride removal by adsorption method using activated alumina modified with different materials and isothermal studies.
- Chapter three is the result-oriented chapter that discusses different parameters affecting photocatalytic degradation of substituted benzoic acids.
- Chapter four covers the analysis of seasonal and spatial variations of water quality of Dulhara and Ved ponds in Ratnapur, Chhattisgarh, India.
- Chapter five examines the degradation of benzoic acid by iron nanoparticles as a photo-catalyst using an advanced oxidation process (AOP). This chapter also discusses the synthesis of Fe nanoparticles via hydrothermal process at ordinary and elevated temperatures.
- Chapter six deals with wastewater treatment using modern methods supported by nanoscale materials.
- Chapter seven discusses the impact of water mismanagement on the environment and suggests preventive measures for proper water utilization.

This book is meant for postgraduate and research scholars in the field of physical sciences, chemistry, and material sciences interested in water treatment, photocatalytic degradation, advanced oxidation process, and solar cell. The book will explore and help readers understand fundamental as well as advanced studies on these processes. Chapters in the book also provide future scope and challenges in both the phenomena, which allow readers to understand basic and current status in the fields. It is hoped that the book shall provide guidelines to all interested in research studies of one sort or the other.

We are highly indebted to our students and learned colleagues for providing the necessary stimulus for writing the book. We are grateful to all those persons whose writings and works have helped us in the preparation of this book. We are equally thankful to the reviewers of

this edited book who made extremely valuable suggestions and have thus contributed to improving its quality.

We will feel highly rewarded if the book proves helpful in the development of genuine research studies. We look forward to suggestions from all readers, researchers, and scholars for further improving the content of the book.

R. M. Belekar
Department of Physics
Institute of Science
Ravindranath Tagore Road
Nagpur, M.S.
India

Renu Nayar
Department of Chemistry
D. P. Vipra College
Bilaspur C.G.,
India

Pratibha Agrawal
Department of Applied Chemistry
Laxminarayan Institute of Technology
R.T.M. Nagpur University
Nagpur, India

&

S. J. Dhoble
Department of Physics
R.T.M. Nagpur University
Nagpur
India

List of Contributors

B.D. Deshpande	Department of Applied Chemistry, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur, Maharashtra, India-440010
Bhavna D. Deshpande	Department of Applied Chemistry, Laxminarayan Institute of Technology, R.T.M. Nagpur University, Nagpur, India–440010
G.D. Sharma	Vice Chancellor, AtalBihari Vajpayee University, Bilaspur, India-495 001
M.G. Bhotmange	Department of Applied Chemistry, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur, Maharashtra, India-440010
M. K. N. Yenkie	Department of Applied Chemistry, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur, Maharashtra, India-440010
Pratibha S. Agrawal	Department of Applied Chemistry, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur, Maharashtra, India-440010
R. M. Belekar	Department of Physics, Institute of Science, Rabindranath Tagore Road, Nagpur-440 001, M.S., India
Renu Nayar	Department of Chemistry, D.P.Vipra College, Bilaspur,C.G., India-495001
Ritesh Kohale	Department of Physics, Sant Gadge Maharaj Mahavidyalaya, Hingna, Nagpur,India, 441110
S.J. Dhoble	Department of Physics, R.T.M. Nagpur University, Nagpur-440033, India

CHAPTER 1

Review on Water Purifications Techniques and Challenges

R. M. Belekar[1,*] and **S.J. Dhoble**[2]

[1] *Department of Physics, Institute of Science, Rabindranath Tagore Road, Nagpur-440 001, M.S., India*

[2] *Department of Physics, R.T.M. Nagpur University, Nagpur-440033, India*

Abstract: Nowadays, the whole world is facing water containment issues caused by anthropogenic sources, including household waste, agricultural waste, and industrial waste. There is a huge impact of wastewater on the environment; hence, the public concern over it has been increased. This led researchers to be motivated and find radical and cheap solutions to overcome this problem. Several conventional techniques, including boiling, filtration, sedimentation, and chlorination, are used for wastewater treatment; however, they have limited scope. Some other methods like coagulation, flocculation, biological treatment, Fenton processes, advanced oxidation, membrane-based processes, ion exchange, electrochemical, adsorption, and UV-based processes have been applied to remove pollutants, but there are still some limitations. This review chapter sheds some light on these traditional and modern methods applied for water treatment, along with their advantages and disadvantages. These methods have the potential to remove pollutants from wastewater, such as natural organic matter, heavy metals, inorganic metallic matter, disinfection byproducts, and microbial chemicals. The potential threats and challenges of using water treatment methods for safe water production have also been discussed in this chapter.

Keywords: Adsorption, Biological treatment, Chemical methods, Electrodialysis, Fenton process, Membrane treatment, Purification methods, UV treatment, Water pollution.

INTRODUCTION

Water is an essential element in natural resources required for the survival of all living organisms, cultivation, and food production. Today, many cities around the world face severe water shortages. About 40 percent of the global food supply requires irrigation, and the industrial process depends on the extensive use of water [1]. Environment and economic development are severely affected by the

* **Corresponding author R. M. Belekar:** Department of Physics, Institute of Science, Rabindranath Tagore Road, Nagpur-440 001, M.S., India; Tel: +91-9822292336; E-mail: rajubelekar@gmail.com

R. M. Belekar, Renu Nayar, Pratibha Agrawal and S. J. Dhoble (Eds)

seasonal availability of water and its quality. Water quality is affected by human activity and is being reduced due to urbanization, population growth, industrial production, and climate change. As a result, water pollution has a severe impact on the earth and its inhabitants [2]. Water treatment produces drinkable water that is chemically, biologically, aesthetically, pure and healthy. The treatment cost for clean raw water is less as it requires fewer purification steps. In rural areas, water usually comes from commonly shared wells, ponds, or hand pumps, whereas in urban areas, it is supplied by municipal corporation water supply [3]. The purification of water involves many steps that are different in different regions and depend upon the quality of water and contaminants. More than 70% of the earth's surface is covered with water, but only around 1% of water is drinkable as per standards. There are many contaminants that make the water unhealthy for drinking purposes, like aluminum, ammonia, arsenic, fluoride, barium, cadmium, copper, *etc* [4 - 6]. There are common treatment methods that include coagulation, sedimentation, biological oxidation, photo-Fenton treatment, advanced oxidation processes (AOPs), oxidation with chemical oxidants, photocatalytic oxidation, membrane processes, electrochemical oxidation/degradation, adsorption, and combined methods [7].

TRADITIONAL WATER PURIFICATION METHODS

The rural communities have adopted simple and traditional methods for removing visible impurities present in the water collected from various sources. Though these methods are not sufficient to provide quality water in urban areas as per international standards, they are more useful in rural areas where the degree of harmful contamination is almost negligible [8]. These methods can easily remove certain bacteria, pathogens, undissolved matter, dust, *etc*.

Filtration

This is the most simple and convenient technique for removing wind-borne impurities like plant debris, insects, dust particles, or coarse mud particles. The raw water collected from various sources passes through a cotton cloth or winnowing sieves, and the impurities get filtered. However, this method cannot be used effectively when water is highly turbid or muddy as cotton cloth or sieve cannot filter fine suspended particles. This method of filtration is popular in many villages of India and other parts of the world, where water is collected from wells or clean ponds [9]. To filter highly turbid water, clay vessels with suitable pore sizes can be used. The turbid water is collected in a clay vessel and allowed to settle. The water in the clay vessel trickles through it, and clear water is collected in another jar. This method of filtration is common in Egypt. In the southern part of India, water purification is carried out using plant parts. The turbid water is allowed to settle and coalesce out using nuts and roots of some locally available plants. It was found that nuts excrete coagulation chemicals upon soaking, which settles most fine suspended particles. Besides that, the wiry roots of some plants are placed in a clay jar that has tiny holes at the bottom. In some artificial ponds in Indonesia, Jempeng stone filters are used for the filtration of water. This Jempeng stone is porous in nature and capable of filtering even highly turbid water [10].

Boiling

Boiling with fuel is the oldest and most commonly practiced water treatment method that kills many bacteria, parasites, cysts, worms, and viruses. It is the simplest and easiest method to remove waterborne pathogens from water. This method of water purification can be implemented anywhere and at anytime as it does not require many accessories. According to WHO, water must be heated until the first big bubble appears in it, which ensures that water is pathogen-free [11]. In an emergency situation such as a flood, pandemic, or war, it is advised to drink boiled water. Besides these advantages, there are certain disadvantages as well. The boiling of water can only kill pathogens and does not remove chemical pollutants like fluoride, arsenic, *etc*. It also cannot remove the turbidity of the water; therefore, pretreatment is required for highly turbid water. Moreover, it consumes traditional fuels (wood, gas, kerosene), which are costly, contributing to deforestation and indoor air pollution. The boiling of water also alters the taste of natural water as it drives out dissolved gases.

Chlorination

Chlorination involves adding a measured amount of chlorine into the water to kill bacteria, viruses, and cysts. Besides, chlorination can also be used for taste and odor control and to remove some gases such as ammonia and hydrogen sulfide. Chlorine is an effective disinfectant widely used in rural common wells to kill most of the bacteria which are responsible for many diseases. Chorine is added to the water as a final stage of water treatment. Chlorine is widely used in many developing countries to prevent waterborne diseases like typhoid and dysentery. The chlorine is added to the water resources in the form of sodium hypochlorite, bleaching powder, or chlorinated lime in a measured amount. The chlorine is also available commercially in tablet form as halazone, Chlor-dechlor, and hydrochlonazone. Depending upon the water quality, the appropriate amount of freshly prepared chlorine is added to water by trained personnel. Chlorine can produce some harmful effects in some cases [12]. The halogen chlorine can easily react with organic compounds present in the water producing trihalomethanes and haloacetic acids. These materials are hazardous to human health and shows

CHAPTER 2

The Fluoride Adsorption Isothermal Studies of Activated Alumina Modified with Different Materials: A Critical Review

R. M. Belekar[1,*] and **S.J. Dhoble**[2]

[1] *Department of Physics, Institute of Science, Rabindranath Tagore Road, Nagpur, M.S., India-440 001*

[2] *Department of Physics, R.T.M. Nagpur University, Nagpur, India-440033*

Abstract: Fluoride in drinking water has become a global problem that has a profound effect on teeth and bones, fostering various health problems. Adsorption is a potential defluoridation technique because of flexibility, cost-effectiveness, environmental friendliness, simplicity in design, relative ease of operation, and capability of producing high water quality. Although activated alumina is an appropriate adsorbent, it has a narrow favorable pH range, a tendency to form toxic aluminum fluoride complexes, and the problem of aluminum metal leaching. This article critically reviews the applicability of activated alumina and its modification by metal oxides, rare earth elements, organic materials, alkaline earth metals, and acid treatment. The effect of process parameters like pH, contact time, adsorbent dose, initial fluoride concentration, and the presence of coexisting ions on the adsorption capacity of fluoride ions is discussed. The adsorption reaction rates were discussed by fitting various rate models into the experimental data and the model equations. The adsorption isotherm models like Langmuir, Freundlich, Temkin, and Dubinin-Radushkevich tested on the adsorption equilibrium data to identify the best fit model for adsorption isotherm are discussed in this chapter. The chapter finally discusses the advantages, disadvantages, and future prospects of all the adsorbents in order to improve their fluoride removal capacity.

Keywords: Adsorption, Activated alumina,alumina modification, Defluoridation, Isotherm models,purification, Kinetic models.

INTRODUCTION

Fluorine is a highly electronegative element in the periodic table, that has the tendency to acquire an electron and form a fluoride ion.

* **Corresponding author R. M. Belekar:** Department of Physics, Institute of Science, Nagpur, M.S., India-440 001; Tel: +91-9822292336; E-mail: rajubelekar@gmail.com

R. M. Belekar, Renu Nayar, Pratibha Agrawal and S. J. Dhoble (Eds)

Fluoride is one of the most commonly found elements on the earth's surface due to natural processes like erosion, volcanic activities, hydraulic leaching, *etc.* [1, 2]. Fluoride is an inorganic, monoatomic, negatively charged ion with the chemical formula F^- whose salts are typically white or colorless, and thus being considered a stable form of fluorine. Fluoride can also be found in natural water resources, animal food, or in the rain, with its concentration increasing significantly upon exposure to volcanic activity or atmospheric pollution derived from burning fossil fuels or industry waste [3]. Many studies have found that fluoride in drinking water prevents at least 25 percent of tooth decay in children and adults, even in an era where there is widespread availability of fluoride from other sources. The optimum concentration of fluoride is essential for the human body. However, a higher concentration that is beyond the safe limit affects plants, humans, and animal life. The safe limit of fluoride in drinking water is 0.5-1.0 mg/L as suggested by WHO standards [4]. Drinking water with a fluoride concentration of 2.5-3.0 mg/L may cause dental fluorosis. The concentration of 3.0-4.0 results in stiffened, brittle bone, whereas a concentration higher than 4.0 may result in crippling fluorosis [5, 6]. The concentrations of fluoride in groundwater are reported to be beyond WHO's safe limit in different parts of the world, such as China, India, Mongolia, Japan, Pakistan, Sri Lanka, Iran, Turkey, Southern Algeria, Argentina, Korea, Mexico, Italy, Brazil, Malawi, North Jordan, Ethiopia, Canada, Norway, Ghana, Kenya, in the states of South Carolina, *etc.* [7].

The duration of continuous intake of fluoride contaminated water and the concentration of fluoride within it determines its impact on human health. Generally, fluoride gets deposited in the joints of the knee, pelvic region, neck, and shoulder bone, making it difficult for a person to walk or move. In severe cases, it may lead to rare bone cancer, spondylitis or arthritis osteosarcoma, spine, major joints, muscles, and damage to nervous system [8]. Therefore, maintaining desirable optimum fluoride levels in drinking water has become a need.

There are several techniques that have been studied for the removal of excess amounts of fluoride from drinking water which includes precipitation, coagulation, dialysis, ion exchange, electro-coagulation, adsorption, membrane filtration, *etc*. However, there are certain limitations of these methods because most of these methods require high operational and maintenance costs, produce secondary pollution (toxic sludge, *etc*.), and require complicated procedures involved in the treatment. Out of these techniques, adsorption is a potential method for defluoridation because of its ease of operation, high productivity, and capability of producing high-quality water. The adsorption technique involves contaminated water entry from the contact bed where fluoride is removed by ion exchange or surface chemical reaction with a solid bed matrix. This technique is prominent over another method of defluoridation because it is straightforward, flexible, and accessible to a wide variety of adsorbents. The adsorption technique is highly efficient and suitable over a wide range of pH to a lower leftover concentration than precipitation [9, 10]. There are a variety of materials reported in the literature used as adsorbents to remove fluoride, which include activated alumina, activated carbon, activated alumina coated silica gel, calcite, activated sawdust, activated coconut shell powder, groundnut shell, activated fly ash, coffee husk, rice husk, magnesia, serpentine, tri-calcium phosphate, activated soil sorbent, bone charcoal, defluoron-1, defluoron-2, *etc.* [11 - 19]. Besides that, there are materials like schwertmannite, which can be used as nano-adsorbent, with an adsorption capacity of 17.24 mg/g, for defluoridation of water [20, 21]. Recently, iron oxide hydroxide has shown its potential for fluoride removal from an aqueous medium with a fluoride removal capacity of 11.3 mg/g [22]. In nano-adsorbents, metal oxide nano-particles are quite promising for the adsorption for their large surface area and porous structure in addition to the short diffusion route [23]. Due to larger surface areas, it is evident that nanosized adsorbents with a strong affinity towards fluoride ions can be suitable tools for enhancing the adsorption capacity in drinking water treatment. However, because of their small size, the isolation of nanosized adsorbents from matrices is difficult for practical use. The Nalgonda Technique is found to be effective and economical in that there is sequential addition of lime, bleaching powder (for disinfection), an alum, or aluminum chloride, but it has some problems associated with operation and sludge disposal [24]. The most common materials currently used in the defluoridation process are activated alumina and activated carbon. The fluoride removing efficiency of these materials is influenced by hardness, pH, and surface loading. The present review paper focuses on the potential of activated alumina and alumina-based adsorbents for fluoride removal from water and wastewater. The adsorption capacities of the modified alumina along with adsorption isotherm models, kinetic models with some of the latest important findings, and a source of up-to-date literature are provided and discussed in this review.

An aqueous solution of fluoride ions containing activated alumina may not be clearly soluble and form various aluminum species, including several fluorides and hydroxyl-aluminum complexes. A series of generalized stepwise equilibrium equations for Al–F complex formation can be expressed as follows:

$$Al^{3+} + F^{-} \rightleftharpoons AlF^{+2} \tag{1}$$

$$Al^{3+} + 2F^{-} \rightleftharpoons AlF_2^{+} \tag{2}$$

CHAPTER 3

Degradation of Substituted Benzoic Acids Related to Structural Reactivity

Pratibha S. Agrawal[1,*], **M. K. N. Yenkie**[1], **M.G. Bhotmange**[1], **B.D. Deshpande**[1] and **S.J. Dhoble**[2]

[1] *Department of Applied Chemistry, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur, Maharashtra, India-440010*

[2] *Department of Physics, R.T.M. Nagpur University, Nagpur, India-440033*

Abstract: The existence of organic acids in aqueous waste continues to be an important environmental concern because of the odor and toxicity they impart to water. The photochemical degradation of benzoic acids (BA) and some of the substituted benzoic acids (SBA), which act as environmental pollutants, are studied in the present investigation using the Advanced Oxidation Processes (AOPs) and combinations of different oxidants and UV irradiation (UV/H_2O_2, UV/TiO_2, UV/ZnO, and Fe(III)-oxalate complex). The photo-oxidative degradation of these pollutants was followed by studying their concentration decay over the period of exposure to the UV-oxidant combination. The degradation kinetics of substituted benzoic acids (SBA) is observed to be dependent on the directory nature of the substituent groups, analyzed by the Hammett constant (σ), where electron-withdrawing groups (EWGs) show positive values and electron-donating groups (EDGs) account for its negative values. These observations figured out the processes that can be efficiently used for the system. Thus, this paper aims to examine parameters that affect the photocatalytic degradation of substituted benzoic acids.

Keywords: Advanced oxidation process, Degradation kinematics, Hydroxyl radicals, Organic acid waste, Photochemical degradation, Photo-oxidative degradation, Substituted benzoic acids, UV/H_2O_2.

INTRODUCTION

Water remains a vital source for the sustenance of life. It is a medium for carrying out all metabolic and physical activities. Though large water bodies are surrounding our planet, less than 0.3% of freshwater resources in the form of

* **Corresponding author Pratibha S. Agrawal:** Department of Applied Chemistry, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur, Maharashtra, India-440010; Tel: +91-9763844660; E-mail: pratibha3674@gmail.com

lakes, rivers, and springs are consumable [1]. Biological bodies and manufactured products contain very little amount of freshwater.

The water cycle plays an important role in regulating water above and below the ground [2, 3].

Lately, due to the population explosion, the demand for water resources has increased, largely disturbing the ratio between the supply and demand. Hence, humans have put tremendous pressure on water resources worldwide. This stress is due to the combined effect of hydrological unpredictability (climatic changes due to global warming, deforestation, floods, and droughts) and extension of human activities (damming, agriculture, diversion, unjudicial use, recreational use, and pollution) [4].

Water can be assumed as an important pillar of the world economy. Approximately 70% of fresh resources are utilized for agricultural activities. Sea, river, and lake routes are common and effective means for the export and import of goods in local, national, and international markets. Water bodies provide a source of seafood as well as act as a means of transport. Industries use gallons of water and its phases as coolants and for heating purposes. Water, an excellent solvent, is used in industries and for domestic work. A number of recreational activities are associated with water, for example, yachting, sailing, rowing, boating, rafting, surfing, *etc*. There are several water parks worldwide that facilitate tourism and help in revenue generation [5].

Science and technology have given a wide outlook to the world. However, for meeting the demands of a large population and in the haste of creating plenty in less time, are not we loosing on something? An increase in industrial activity has led to the unjudicial use of fresh water resources, causing its scarcity. Moreover, industrialization has also led to the pollution of water bodies. Pollution means undesirable and unwanted bodies that change the physical and chemical composition of water air, soil, *etc*. Nature has its purification process, which removes the biodegradable waste by biological process. The broken contaminants settle and are absorbed by the soil. Though the self-purification process cannot make the water drinkable, it can be used for cleaning, washing and gardening purposes. However, large dumping of industrial, domestic and sewage wastes into fresh water resources make them unfit for consumption, and self-purification fails after a certain degree of pollution in water. Industrial waste (chemicals such organics and inorganics, resins, oils), agricultural runoff (pesticides, herbicides, weedicides), and untreated sewage (microbes, pathogens, virus,) contain non-biodegradable compounds that affect the entire ecosystem. Surface and ground water degradation due to these chemicals even in low concentrations can cause serious problems for humans and wildlife. Clean drinking water is the right of every individual, after knowing the source of water contamination to be industrial effluent, certain legal standards were laid in 1972, CWA (Clean Water Act) having the goals as Zero discharge, Fishable and Swimmable water and No Toxicity in safe drinking water [6, 7].

To limit water pollution we must know the source and ways to overcome it and be the part of the solution. Pollutants in water bodies lead to bacterial contamination and eutrophication. Industries effluents containing toxic compounds enter the food chain of aquatic organisms that ultimately affect higher hierarchy. Sudden temperature change due to industrial water may affect the oxygen content leading to high fish mortality. The runoff from construction sites and farms makes the water unclear, hence, affecting photosynthesis by obstructing the sunlight to reach aquatic plants. As compared to ground water that moves miles unseen, surface water can be easily cleaned. Ground water is self-purified when it passes through the porous and fine-grain aquifer. It is more susceptible to contamination where population density is more [8]. Groundwater chemicals can enter through the Point source (oil spills, leakage in pipe, treatment plants effluent, factories, refineries) and Nonpoint source (fertilizers and pesticides runoff by rain, contamination through soil/ground water system by improper disposal) or atmosphere (rain, gaseous emissions from automobiles, factories, and even bakeries) [9].

Pollution is imperative to industrialization as it is to population explosion. Environmentalists, conservationists, NGOs, and government and non-government organizations are imposing stringent rules and regulations on the wastewater management and conservation and treatment of effluent before disposing of it in the large water bodies. The degree of treatment required for a wastewater depends mainly on discharged requirements of effluents and the nature of water pollution it contains. The processes used for the treatment of water are primary, secondary and ternary [10].

Primary methods are used for removing suspended solids and floating materials. This can be done using Screening, Sedimentation, Flotation, Equalization, Neutralization, Stripping and Coagulation. Primary methods help to reduce biological oxygen demand (BOD_5), total suspended solid (SS) and oil and grease up to 25-50%, 50 to 70%, and 65% respectively. Organic nitrogen and phosphorous are removed also considerably [11 - 13].

Secondary methods further treat the effluent to remove chemical oxygen demand COD by 90%, BOD_5 by 85% and SS to 70%. Some processes used to treat primary wastewater are extended aeration, contact stabilization, membrane

CHAPTER 4

Analysis of Seasonal and Spatial Variations of Water Quality of Dulhara and Ved Ponds in Ratanpur, Chhattisgarh, India

Renu Nayar[1,*], **G.D. Sharma**[2], **Ritesh Kohale**[3] and **S.J. Dhoble**[4]

[1] *Department of Chemistry, D.P. Vipra College, Bilaspur, C.G., India-495001*

[2] *Atal Bihari Vajpayee University, Bilaspur, India-495 001*

[3] *Department of Physics, Sant Gadge Maharaj Mahavidyalaya, Hingna, Nagpur, India, 441110*

[4] *Department of Physics, R.T.M. Nagpur University, Nagpur, India-440033*

Abstract: Pollution load, rising population, and scarcity of water have drawn special attention for the management of water resources such as pond water. The present investigation was carried out at Dulahra and Ved ponds in Ratanpur, Bilaspur District. The seasonal deviations in water such as transparency, temperature, pH, dissolved oxygen, nitrate, phosphate, biological oxygen demand (BOD), total dissolved solids (TDS), and total suspended solids (TSS) were evaluated. In the contemporary study, the BOD standards were considerably higher than World Health Organization (WHO) standards (5 mg/l). The water samples were collected from each site at outer (about 100-150 meters) and internal (10 m from the shoreline) localities. The highest mean value of BOD, *i.e.*, 32±4.6, was found at the north peripheral S-1 in the summertime. In the summer season, maximum mean BOD 39±2.1 was found at S-2 (West peripheral) in Ved Pond. It indicates the biological pollution load on the water body in the site of North peripheral in Dulhara pond and West peripheral in Ved Pond in the summer season. Low Secchi depth readings such as 20±1.0 at S-2 North peripheral site during summer seasons are indicative of reduced water clarity that is habitually related to the existence of suspended particles and algal tinges. We also found the maximum value of total suspended solids on the north side of the pond, where the transparency of water was also very low. A transparency value of 37.0±0.40 was noted at S-1 in the East marginal sites and 30±0.22 at the East inner sites in the rainy period at the Ved pond. The transparency of the water physique is exaggerated by the elements like planktonic growth, rainfall, the sun's location in the sky, the angle of incidence of rays, cloudiness, electiveness, and turbidity due to deferred inert particulate material. Our outcomes suggest that the lowermost water transparency value was 16.0 ± 0.41 at S-1 in the North marginal sites for the duration of summer. The concentration of Calcium ions was much above the WHO recommended value of 75 mg/l at almost all the sites and both ponds during the study period. Numerous indicators and catalogues have been

* **Corresponding author Renu Nayar:** Department of Chemistry, D.P. Vipra College, Bilaspur, C.G., India-495001; Tel: +91-9977413760; E-mail: nayar.renu@yahoo.co.in

R. M. Belekar, Renu Nayar, Pratibha Agrawal and S. J. Dhoble (Eds)

established in this particular study to evaluate water quality in intermediate water bodies. For transparency studies,low-cost Secchi disk was used.

Keywords: Dulahra tank, East marginal sites, Monthly variation, Physico-chemical parameters, Pond water, Seasonal variation, Secchi disk, Water bodies, Water quality parameters.

INTRODUCTION

Domestic inlets, such as aquatic ecological units where entire water assembles with fresh water from significant sources, endure a resemblance to superficial ponds as they regularly proceed as shallow water bodies disjointed from the enormous water pools by an obstruction. Their physicochemical appearances and irregularity of the entering mutability differ significantly between annual progressions. During the earlier epochs, the formation of human societies and metropolitan growth on the earth's surface had straightforward influences on these ecological units. The modification of ecological systems, as well as the endless accumulative nutrient releases from agronomic and industrialized undertakings, have commanded the ecological regions in the surrounding. Water superiority may be influenced by the resident geology and environment, as well as human usages like sewage dispersal, industrialized contamination, and use of water bodies as a cleansing, for cloths, animals and motor vehicles cleansing, *etc*. Water is not only essential to life but is also essential for industrial processes. In industries, it is used in steam generation. Water is used in chemical plants for cooling purposes. A considerable amount of water is also used for solution, and dilution purposes in chemical plants [1]. The majority of people in developing countries do not have access to clean water or any other form of sanitation. Therefore, millions of people are suffering from diseases related to water, sanitation, and hygiene, such as diarrhea, skin diseases, and trachoma [2]. Man uses water for the production of steel, rayon, papers, and textiles, but also for air conditioning and irrigation purposes [3]. Water is therefore important for everything in our sphere to cultivate and grow. Water that is free of disease-generating micro-organisms and biochemical constituents poisonous to well-being is called potable water. Water polluted with either internal or industrialized garbage is called non-potable or polluted water [4]. As we all know, natural life was initially originated in water. The worldwide water shortage is increasing, and as such, it is essential to yield new water bases that we may previously have thought of as unapproachable. Water is one of the most significant elements of the existing creatures in the world [5]. Water is a widespread and outstanding solvent as it liquefies in a wide variety of materials than other solvents [6]. So, no other composite can be associated with water as a solvent. Water has numerous exclusive and worldwide physiognomies that make it appropriate for living beings to endure dissimilar circumstances for life. Water excellence eminence is a solitary term that means lending a hand to the assortment of suitable management procedures to encounter varied problems [7]. The hydrosphere covers more than 75% of the earth's surface as freshwater. Seawater, rivers, oceans, lakes, and pond water form a hydrosphere that encompasses more than 35 ppt of liquefied solids. Normal water always contains liquefied and suspended substances of biological and inorganic mineral. Most pulverized water surrounds dissolved materials while superficial water is rich in the adjourned matter [8].

The rapid growth of urban areas directly or indirectly affected the existence of the ponds, such as over-exploitation of resources and improper waste disposal practices. The objective of primary concern is to provide potable water. Although humans tend to protect themselves from harmful micro-organisms and undesirable or harmful chemicals, they pollute our rivers, lakes, and oceans [22]. Regardless of advancements in drilling, irrigation, and decontamination, the position, excellence, magnitude, possession, and mechanism of drinkable water residues remains a major anthropoid concerns (Cunningham, W. P.). Ratanpur is one of the famous holy places that is situated around 25 km from Bilaspur –Korba main road, Chhattisgarh, India, as indicated in Fig. (**1a**). It is a well-known fact that Ratanpur is in Bilaspur district in the Indian state of Chhattisgarh, situated at 22.30N and 82.170E, with an average rainfall varying from 135mm to 445mm and a humidity of 34 percent. The town is popular as a religious center, and many Hindu devotees come here to offer their prayers. Perhaps due to various temples of different eras/periods and other religious purposes, so many small and large ponds/ tanks are available. That is why Ratanpur is popularly known as 'Temple City' as well as 'City of Ponds'. Retrospectively, temples correlate with more than a hundred small and large ponds. As quoted in the history, there were more than 150 ponds during the early days. Of these ponds, Dulhara, Bikma, Ved, Ratneshwar, and Krishnajuni are large ponds.

Objectives of the Present Work

The physico-chemical investigation of pond water in regions of India where widespread human activities are taking place is extremely essential [12]. The pollution of pond water by inorganic chemicals, organics, and micro-organisms evidently takes place since inappropriate drainage schemes, septic tanks, and solid waste disposal are still being utilized. A literature review reveals that no organized study has been statistically analyzed concerning the excellence of surface water in Ratanpur and its nearby rustic expanses. Hence, contemporary work was carried out to examine the quality of water in Ratanpur and its surrounding areas, where some major ponds are located and used by people in the form of different activities [13]. To uncover the specimen locations throughout

CHAPTER 5

Nanoparticle-aided AOP for Treatment of Benzoic Acid

Bhavna D. Deshpande[1,*], **Pratibha S. Agrawal**[1], **M.K.N. Yenkie**[1] and **S.J. Dhoble**[2]

[1] *Department of Applied Chemistry, Laxminarayan Institute of Technology, R.T.M. Nagpur University, Nagpur, India–440010.*

[2] *Department of Physics, R.T.M. Nagpur University, Nagpur, India-440033*

Abstract: Advanced oxidation process (AOP) degrades a number of non-degradable organic compounds in low concentrations, saving time and energy. Benzoic acid and its derivatives are readily used in pharmacy, textile, and dyes industries. Through these applications, benzoin acid enters the ecosystem, which leads to its accumulation and various health hazards. In the present study, the degradation of Benzoic acid was studied using Iron nanoparticles as heterogeneous photocatalyst and hydrogen peroxide as an oxidizing agent. This paper also discusses the synthesis of Fe nanoparticles *via* hydrothermal process at ordinary temperature and elevated temperature. The powder samples were characterized by X-ray diffraction (XRD), Scanning Electron Microscope (SEM) and Energy dispersive analysis of X-rays (EDAX). The percentage degradation of benzoic acid using goethite (α-FeOOH) and hematite (α-Fe_2O_3) was 49.02% and 90.90% with the nano concentrations of 0.07g and 0.05g, respectively using visible light, in addition, the hydrothermal model of nanoparticle synthesis proved affordable, efficient and eco-friendly.

Keywords: Advanced oxidation process (AOP), Hydrothermal process, Nano-particles, Non-degradable, Photocatalyst, Heterogeneous, Goethite, Hematite, Iron nanoparticles.

INTRODUCTION

In view of the ever-increasing world population, freshwater scarcity has become the world's most critical environmental issue that plagues the earth today. Although Earth is surrounded by 71% water, 97.5% being salty, only 2.5% of freshwater remains usable [1]. Due to rural migration, industrialization, and the growing needs of an exponentially increasing population, the usage of freshwater

* **Corresponding author Bhavna D. Deshpande:** Department of Applied Chemistry, Laxminarayan Institute of Technology, R.T.M. Nagpur University, Nagpur–440010, India; Tel: +91-9881370448; E-mail: dnd.bhavna@gmail.com

R. M. Belekar, Renu Nayar, Pratibha Agrawal and S. J. Dhoble (Eds)

has increased over the years, which has led to the depletion of freshwater resources that have made it an expensive commodity [2]. Climatic changes due to global warming remain a major factor in freshwater depletion [3]. Freshwater resources are inevitable for the sustainability of society [4]. Various researches suggest that by 2025, the world would be under acute water stress [5, 6]. Regardless of this fact, in most developing countries, industrial effluents are discharged into the water bodies without any proper treatment neglecting the guidelines laid down by governments and international bodies [7]. Wastewater contaminants include inorganic and organic pollutants, heavy metals [8], refractory organic pollutants [9] and many other complex compounds. Aromatic compounds (benzoic acids, phenols and their respective derivatives) are widely used as precursors in pharmaceutical, textile, food and cosmetic industries [10]. The industrial usage of natural resources can be curtailed by reusing and recycling wastewater produced in industries by various methods such as physio-chemical, chemical, biological, electrochemical, oxidation and photocatalysts and combination of the mentioned processes [11]. Hence, innovative, highly proficient, and low budget technologies for wastewater treatment is today's necessity [12]. Conventional methods clubbed with newer rapid technologies can enhance the reaction rate. Some rapid and significant processes such as bioremediation, adsorption, photo catalytic oxidation are being used to treat the polluted waters [13, 14].

Advanced oxidation processes (AOPs) are promising techniques used in the past decades for the complete mineralization of organic content, hazardous pollutants and non-biodegradable matter in wastewater [15]. AOPs have gained importance because of their fast reaction rates, moderately small setup, reduced toxicity and perhaps complete mineralization of pollutants, no sludge formation, and no further treatment of the product formed [16, 17]. AOP is a special class of oxidation grounded on the production of $OH^{\cdot}$ radicals in the aqueous phase leading to the destruction or disintegration of their molecular structure resulting in losing their chemical identity [13]. Hence, refractory organic matter is oxidized into carbon dioxide, water and biodegradable inorganic waste thus treating the water. $OH^{\cdot}$ radical is a non-selective, highly reactive, and short-lived oxidizing agent which has an oxidizing potential ranging between 2.8V(pH 0) and 1.95 V(pH 14) *vs* Saturated Calomel Electrode(SCE), a commonly used reference electrode in water treatment techniques [18, 19]. Hydroxyl methods can be introduced into the reaction mixture using different techniques such as a combination of oxidizing agents (using O_3 and H_2O_2), irradiation of UV light or ultrasound, and catalysts (such as Fe^{2+}) [20]. The intermediate formed during the course of the reaction depends on the substrate compound that ultimately oxidizes to CO_2 and NO_3^-. Moreover, species such as chlorinated alkenes are more susceptible to hydroxyl radical attack, as compared to saturated molecules (*i.e.* alkanes). It is true that AOP processes are highly efficient but should always be used after conventional methods have significantly degraded the biodegradable waste [21]. The application of AOP at the correct locus in a process chain can increase the efficiency of the process by oxidizing the pollutant and mineralizing it completely into non-toxic and/or inorganic byproducts [22].

Recently, field application of AOPs combined with conventional methods is much in use [23]. Selection of treatment, compatibility of all selected processes and cost effectiveness of the total setup remains a task. Certain factors that must be taken into consideration are the nature of the solution under investigation and parent contaminant to be removed; selection of primary and secondary methods [24], efficiency post AOP and cost relevance, long term sustainability and eco-friendly approach [25]. The parameters determining the efficacy of the oxidation process are pH, temperature, concentration of pollutant and hydrogen peroxide, the reaction contact time, dose of catalyst, wavelength and intensity of UV radiations [26]. From an environmental point of view, one must take cognizance that the intermediate formed during the reaction should not be more toxic than the initial pollutant under study. Thus, it is unconditionally important to know the progress of the reaction and the final product to be characterized. Although the degradation of organic pollutants by hydroxyl radical is stepwise, a plethora of intermediates is formed, with different oxidation states before the complete mineralization into carbon dioxide and water [27]. Identification and quantification of all intermediates and determination of the kinetics and mechanisms of the individual is a daunting task. Moreover, while studying actual industrial effluents, which involve complex mixtures, complexities can be many folds and some of them might be resistant to degradation and accumulate in the system [28, 29]. Hence, degradation pathways and mechanisms can be still considered in their infancy for most of the AOPs. In comparison to conventional AOPs, photochemical and photocatalytic processes have gained a huge response to the treatment of polluted waters and effluents. It is cost effective and eco-friendly option for effluent treatment in tropical and subtropical regions. Due to the wide applications of AOPs and because of their complex mechanism, the intermediate formed could be more toxic than the parent and the excess use of peroxide and precipitation of iron during the Fenton reaction and its removal needs further study [30].

Nano means 'dwarf"; Richard Feynman laid the foundation for nanotechnology. The term nano-technology was introduced by Norio Taniguchi in 1974 [31]. Nano materials (NM) are emerging fields, which are finding varied applications in today's world. Nano materials are claimed to be environment friendly, on the basis of processing efficiency, enhancing reactivity, surface area, economic benefit and low energy consumption [32]. Nano materials usually have a larger specific area and hence, have a high density at active sites, which results in

CHAPTER 6

Wastewater Purification Using Nano-Scale Techniques

Bhavna D. Deshpande[1,*], **Pratibha S. Agrawal**[1], **M.K.N. Yenkie**[1] and **S.J. Dhoble**[2]

[1] *Department of Applied Chemistry, Laxminarayan Institute of Technology, R.T.M. Nagpur University, Nagpur, India–440010*

[2] *Department of Physics, R.T.M.Nagpur University, Nagpur, India-440033*

Abstract: This paper presents an exhaustive study of modern methods used to purify water with the support of nanomaterials. For deriving maximum benefits from nanotechnology, the environmental sustainability of the nano-particles must be assessed. Nanoparticles possess useful characteristics contributing to water treatment and the removal of numerous pollutants. Materials such as zeolites, chitosan, MWCNT, nano-composites (Fe_3O_4/TiO_2, $GO/FeO{\cdot}Fe_2O_3$, *etc.*), nano-oxides (ZnO, TiO_2, Al_2O_3, Fe_2O_3, Fe_3O_4, *etc.*) and MOF (MOF-808, Cu-terephthalate, $CoFe_2O_4$ /MIL-100(Fe), UiO-66-NHC(S) NHMe, *etc.*) have been included in the study including their apparent functionality in treating contaminated water streams. Additionally, known methods to synthesize these nano particles from diverse sources have been studied. The review highlights the removal of pollutants (non-biodegradable, heavy metals, inorganics, and organics) by adsorption using photo nano adsorbents. Devoid of any recognized standards, the performance of the nanomaterials in wastewater treatment needs further research. With the further advancement of nano technology, ideological guidelines along with general cons and future challenges affecting humans and the ecosystem have been reported to provide further scope for research in this domain.

Keywords: Advance oxidation process, Adsorbent, Nano-materials, Non-biodegradable, Oxidation, Photo-catalyst, Water treatment.

INTRODUCTION

The man's hunt for information, knowledge, and facts has led him to imagine and evolve new components. With the new inventions, the dimensions have been reduced, and the efficiency has increased several folds.

* **Corresponding author Bhavna D. Deshpande:** Department of Applied Chemistry, Laxminarayan Institute of Technology, R.T.M. Nagpur University, Nagpur, India–440010; Tel: +91-9881370448; E-mail: dnd.bhavna@gmail.com

R. M. Belekar, Renu Nayar, Pratibha Agrawal and S. J. Dhoble (Eds)

A few decades ago, the technology was micro and macro-based, where micro-energy and microparticles were used by engineers in microchips, micrometers, microcells, and microprocessors. It is evident that miniaturization of devices from the micron to nanoscale improves experimental efficacy, although the proper demarcation between the two remains unclear [1]. Microparticles are microscopic in size, varying between 0.1 and 100 μm. Microparticles such as pollen, powdered sugar, sand, dust, and flour, which we come across daily [2]. Printer heads, sensors, and integrated circuits are examples of micro-scale products. Microparticles available commercially include ceramics, glass, polymers, and metals. They have been employed in wide applications such as pharmaceuticals, cosmetics, imaging, coating, electronics, and printing media, and have shown wide application in wastewater treatment. Micro-particles may have more than two components to exhibit different properties [3]. Due to their high porosity, non-toxicity, and high surface area to volume ratio, calcium carbonate micro-particles are used in various industrial applications, such as material filling, biomedical, the food industry, and environmental studies [4]. Cross-linked poly microparticles were prepared using an emulsifier-free and a single–step swelling polymerization process. Various organic pollutants are readily adsorbed by polystyrene microparticles. The application of a particle depends upon its size and shape [5]. Polymeric microparticles infused into ceramic, alumina, silica carbide, and titanium oxide were used for the decontamination of potable water [6]. Palladium microparticle exhibits catalytic activities, and it reduces dissolved oxygen in water and nitrobenzene to aniline [7]. Silver-microparticles complexed with chitosan were prepared using crosslinking agents to probe the behavior of pesticides such as methyl parathion (MP) [8]. Hence, magnetic alginate microparticles were used for the purification of α-amylases [9], providing a means for soil and water pollution remediation [10].

Today, the scale has been further pulled down to nano, increasing the strength, chemical reactivity, and surface area and at the same time reducing weight. Micro and nanoscale phenomena are widely used to overcome traditional limits on materials, systems, and technologies. The size and characteristics of particles determined by their growth mechanism define their applications. The nano era has reached every nook and corner of the world. Technologies are blending with nanotechnology, creating a change in fascinating ways. Nanoparticles have shown wider applications in various fields as compared to microparticles, which have limited applications. Micro- and nano-particulates have been used in the manufacturing sector, the electronic world, such as LED bulbs, tubes, TV, radios, and detectors on a pre-clinical basis as new drug-delivery devices, and in the water treatment process. Hybrid microparticles increase the adsorption capacity and hence, are more effective. The synthesis of micro and nanoparticles requires a stable chemical environment. The particle size of both micro and nano depends upon pressure, temperature, and concentration. Researchers have made an evolution in bringing out various applications of nanoparticles. The thought of being able to live in a world free from environmental issues, diseases, species extinction, starvation, and poverty is everyone's dream; nanotechnology has helped to achieve that goal in various fields. This review highlights the applications of nanotechnology in the purification of water, their synthesis, and their toxicity to the environment and humans. The review suggests that there exists enough room for further work in terms of the impact and risk of nanoparticles on the ecosystem.

GENERAL APPLICATION OF MICRO AND NANOPARTICLES

Nanomaterials have shown immense potential in the fields of science and technology. They have shown immense potential in capturing solar energy like solar cells, medicines, and weather monitoring. It has paved the way for a variety of businesses, companies, commercial and industrial products, aerospace, nuclear, biomedical, electronics, energy, and metallurgical engineering. Calcium nano/microparticles have various applications in different fields such as paper, plastics, paints and coatings, medicines, the environment, catalysts, chemicals, and food industries, and wastewater treatment. The properties like high surface area, porosity, biocompatibility, and ability to alternate from micro to nano make it a versatile compound to be applied in various fields [4]. Fig. (**1**) depicts the wide applications of nanoparticles.

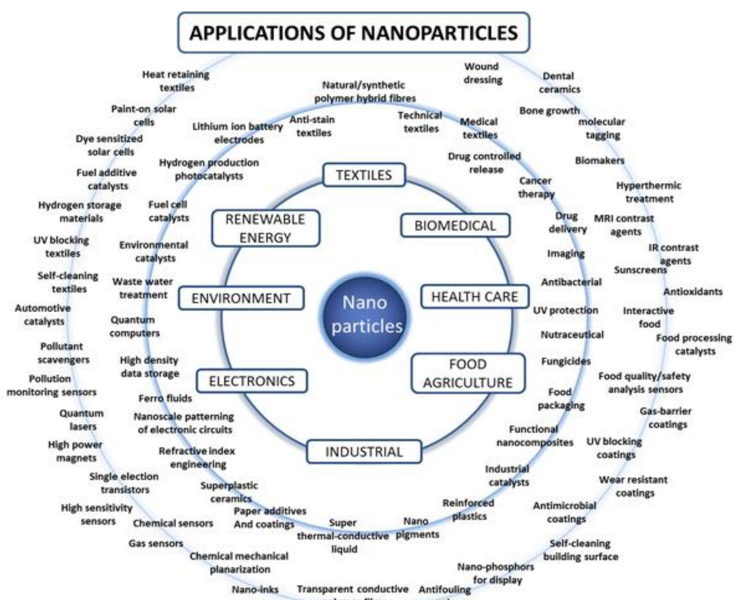


Fig. (1). Nano-particles in various fields (on line source chandanashaw.svbtle.com).

CHAPTER 7

Utilization of Water: Environmental Impact and Health Issues

Bhavna D. Deshpande[1,*], **Pratibha S. Agrawal**[1], **M.K.N. Yenkie**[1] and **S.J. Dhoble**[2]

[1] *Department of Applied Chemistry, Laxminarayan Institute of Technology, R.T.M. Nagpur University, Nagpur–440010, India*

[2] *Department of Physics, R.T.M. Nagpur University, Nagpur-440033, India*

Abstract: The availability of pure drinking water to individuals reflects the progress of any region, which is linked directly with the quality of life across the globe. Variations in the quality and quantity of water systems control all aspects of human life. Both its shortage and excess affect the growth and development of the community. The utilization and conservation of our water world must be an integral part of sustainable development and should be appealed to by all sectors. While effective wastewater treatment has the tendency to recover the water, integration of all policies with periodic improvement using research outcomes is still essential. In order to tackle the challenges in the coming decades, it is important that all stakeholders are sensitized about the current scenario, future needs, and the need for a proper scientific and rational approach to moderate the issues and challenges collectively. Integrated Water Conservation Techniques are acknowledged as the only sustainable solution to water scarcity.

Keywords: Adsorbent, Advanced oxidation process, Photo-catalyst, Nano-materials, Non-biodegradable, Oxidation, Water treatment.

INTRODUCTION

Water is a basic supporting system for the sustainable development of society as well as the country. The importance of water remains as there exists no alternative or substitute for it. In spite of large water bodies surrounding the earth, water scarcity has engulfed large areas, affecting the normal life of humans. Changing lifestyles, climatic conditions, population explosions, urbanization, and industrialization have changed the quality as well as the availability of this indispensable resource worldwide. Pollutants emerging from factories, industries,

* **Corresponding author Bhavna D. Deshpande:** Department of Applied Chemistry, Laxminarayan Institute of Technology, R.T.M. Nagpur University, Nagpur–440010, India; Tel: +91-9881370448; E-mail: dnd.bhavna@gmail.com

R. M. Belekar, Renu Nayar, Pratibha Agrawal and S. J. Dhoble (Eds)

and institutions, agricultural runoff, and domestic sewage directly or indirectly enter aquatic bodies, disturbing the entire ecosystem.

The pollutants present in water can be categorized as biological, organic, inorganic, radioactive, and thermal pollutants. Biological contaminants include viruses, worms, planktons, fungi, bacteria, and protozoa, which are responsible for spreading diseases in humans and animals. Organic pollutants are highly toxic. Their presence in low concentrations leads to severe genetic disorders. These include dues, detergents, sewage, phenols, pharmaceuticals, pesticides, oils, *etc*. Inorganic pollutants determine the quality of water. It includes mineral acids, inorganic salts, metal compounds, trace elements, and organometallic compounds. Radioactive contaminants emit radiations that affect humans and the environment adversely. Their presence in nature may be due to mining activities and processing, nuclear weapon manufacturing, isotopes used in medical fields and industrial and research applications. Generally, water is used as a coolant in many industries. Differences in temperatures of coolants and large water bodies affect the aquatic ecosystem, causing thermal pollution. The industrial boom has led to an increase in water pollutants and the depletion of freshwater resources. It is imperative that pollutants adversely affect the environment and cause a scarcity of water.

To cater to the extended human needs, this problem may arise in the future. There are various reasons for water scarcity, most likely contamination through organic and inorganic chemicals, natural calamities, excess and unjudicial use, population explosion, underdeveloped management systems, *etc*. Climatic changes are supposed to aggravate these problems more in the near future. The unavailability of safe freshwater has led to severe health issues because of lack of sanitation and exposure to microbes through the food chain, affecting people worldwide. Pollution of freshwater resources exposes humans to waterborne diseases in various ways [1]. This paper emphasizes problems faced by the planet today in terms of quantity and quality of freshwater. Integrated techniques, along with traditional techniques, can be a viable tool to increase storage capacity. Water conservation and management can be made effective with good governance, policies, participation of stakeholders, spreading awareness, public-private partnership, and advanced techniques.

HUMAN DESIRE AND EARTHS LIMIT

History has witnessed that all the civilizations in the past have flourished near the rivers. About 5000 years ago, humans used water for irrigation purposes. They controlled and diverted river water to their fields; hence, water was primarily used for irrigation. Water remains an inevitable source for domestic as well as economic use then and even now. The flow chart below (Fig. **1**) shows the water usage timeline of humans.

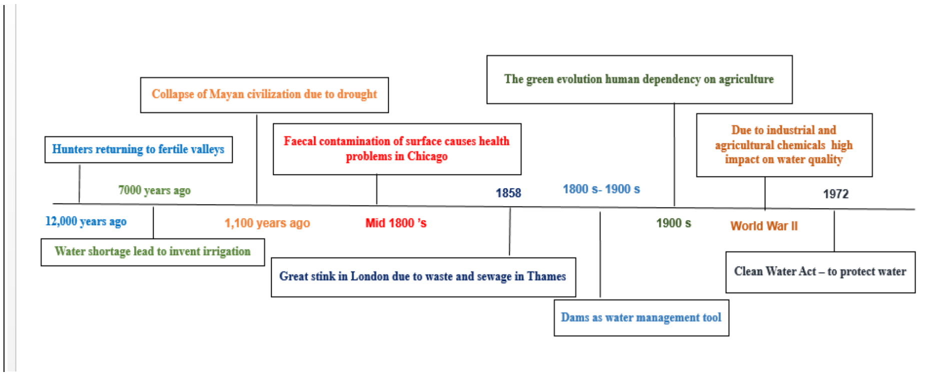


Fig. (1). Flow chart showing water usage timeline of humans.

The use of natural resources and urban development has brought environmental changes. Our actions have changed the landscapes and disrupted river flow, reallocating forests, hence disturbing wildlife, for our survival, which has affected our environment [2]. With 70% of oceans that cover our planet, the real usable water remains only 2.5%, of this, only approximately 1% remains accessible for human usage which is found in reservoirs, groundwater, lakes, ponds, and rivers. These resources are replenished by rainwater and snowfall; hence, these are the only sources of our sustenance. Today, the demand for freshwater has increased largely for domestic purposes, irrigation, and municipal and industrial usage [3]. Largely, water is used for household water (washing machine, sink, shower, cooking), communities (fire fighting, public areas, hotels, clubs, shops, public drinking, schools, colleges, and libraries, public gardens and parks, malls, *etc.*) farming (irrigation, spraying fertilizer, herbicides, and pesticides, dairy, vegetables, and grain crops), generating electricity, industries recreation, and transportation (water parks, fountains, golf courses, *etc.*).

For years, we have enjoyed the fruits of abundant resources without actually considering what might be the ill effects of their unjudicial use. Today, nearly 40% of the world's population is living in water stress; this count is expected to rise to 50-65% by 2025, and about 90% of the population by 2050 will grow in the water-scarce areas [4].

In the last few years, global warming has led to frequent droughts affecting the world economy [5]. The stress on the water is further added due to unplanned agricultural and industrial usage along with improper and mismanaged use of

SUBJECT INDEX

A

B

C

D

E

F

G

H

N

O

P

R

S

T

U

V

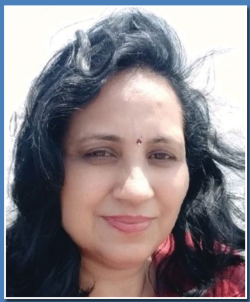
W

X

Z

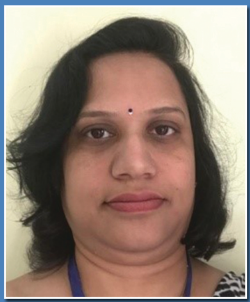
R. M. Belekar

Dr. R. M. Belekar obtained MSc degree in Physics and Ph.D. in nano-alumina-based ceramic materials from R.T.M. Nagpur University. Besides that, he has qualified for the UGC-NET, SET, and GATE examinations with a good rank. He is currently working in the Department of Physics at the Institute of Science, Nagpur. He is working on research fields like water treatment, nanomaterial synthesis, magnetic materials, and luminescence. He is a recognised Ph.D. supervisor, and he has successfully guided 4 MPhil students, 20 M.Sc. projects, and 3 Ph.D. students. He has published more than 24 research papers in international journals, presented 14 research papers in conferences, and is the author of 3 books.



Renu Nayar

Dr. Renu Nayar has obtained her MSc degree in Chemistry from Model Science College, Avadhesh Pratap University, Rewa(M.P.), India in 1993 and a PhD in water pollution from Guru Ghasidas University, Bilaspur in 2006. She is working in the fields of water pollution and material science. She has successfully completed two research projects sanctioned by UGC Bhopal and one ongoing project sanctioned by the state planning commission. She has published 20 research papers in international and national reviewed journals. Some of the chapters are published by Elsevier, Springer and other edited books. Presently, two PhD students are working under her guidance.



Pratibha S. Agrawal

Dr. Pratibha S. Agrawal is working in the fields of ultrasonics and environmental chemistry. She is a recognised PhD supervisor at RTM Nagpur University and 10 students have been awarded PhDs and another 5 are working under her guidance. She has published more than 84 research papers in national and international journals and received recognition at various conferences. She has also contributed a chapter in the book "Adsorption of Reactive Dye 21 on Fly ash and MnO 2 Coated Flyash Adsorbent: batch and continuous studies" published by Apple Academic Press. Moreover, she has successfully completed three major research projects under the UGC, New Delhi.

S. J. Dhoble

Prof. Sanjay J. Dhoble obtained his M.Sc. degree in Physics from Rani Durgavati University, Jabalpur, India in 1988 and Ph.D. degree in 1992 from Nagpur University, Nagpur. He is presently working as a Professor in the Department of Physics, R.T.M. Nagpur University, Nagpur, India. During his research career, he has worked on the synthesis and characterization of solid-state lighting materials and radiation dosimetry phosphors. Dr. Dhoble Granted 20 patents and more than 747 research papers published in Scopus indexed journals with h-index 38 and citations 8725 on Scopus. He also authored 24 International books. Dr. Dhoble is Editor of Luminescence: The Journal of Biological and Chemical Luminescence, John Wiley & Sons Ltd. He is also recipient of India's Top Faculty Research Award-2018 by Careers 360.